Postural Control Measures of Neuromuscular Fatigue in Rugby Union

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Certificate of Original Authorship

I, Jordan Troester declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Health at the University of Technology Sydney. This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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List of Publications Included in This Thesis

Published

Troester, J., Jasmin, J., & Duffield, R. (2018). Reliability of single-leg balance and landing tests in rugby union; prospect of using postural control to monitor fatigue. *Journal of Sports Science and Medicine, 17*, 174-180.

Troester, J., Jasmin, J., & Duffield, R. (2019). The influence of training load on postural control and countermovement jump responses in rugby union. *Science and Medicine in Football*, DOI: 10.1080/24733938.2019.1598621

Troester, J. & Duffield, R. (In Press). Postural control responses to different acute and chronic accumulated training load profiles in professional rugby union. *Journal of Strength and Conditioning Research*.

Troester, J. & Duffield, R. (2019). Monitoring residual 36 h post-match neuromuscular fatigue in rugby union; a role for postural control? *European Journal of Sport Science* (2019), DOI: 10.1080/17461391.2019.1606941

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List of Abbreviations

ACWR	Acute to chronic workload ratio
AP	Anterior-posterior vector
AU	Arbitrary Units
CK	Serum Creatine Kinase
$cm \cdot s^{-1}$	cm per second
CL	Confidence limits
CMJ	Countermovement Jump
ConDur	Concentric Duration
ConIMP	Concentric Impulse
CoP	Centre of Pressure
CV	Coefficient of Variation
D	Dominant leg
EC	Eyes Closed
EccDur	Eccentric Duration
EccRFD	Eccentric Rate of Force Development
EO	Eyes Open
ES	Effect Size
FFP	Functional Fatigue Protocol
FT:CT	Flight Time to Contraction Time ratio
GRF	Ground Reaction Force
h	Hours
HSR	High Speed Running
ICC	Intraclass Correlation coefficient
IMP	Relative landing impulse
JH	Jump height
$m \cdot s^{-1}$	Metres per second
MF	Mean Force
ML	Medio-lateral vector
MP	Mean Power
ND	Non-dominant leg
NMF	Neuromuscular Fatigue
PF	Relative peak landing force
RFD	Rate of Force Development
SD	Standard deviation
sRPE-TL	Session rating of perceived exertion training load
SV	Sway Velocity
SV-AP	Antero-Posterior Sway Velocity
SV-ML	Medio-lateral Sway Velocity
SWC	Smallest Worthwhile Change
TD	Total distance
TL	Training Load
TTS	Time to Stabilisation
v	Vertical
vGRF	Vertical Ground Reaction Force

Abstract

Managing player load, fatigue and recovery in rugby union is deemed important given the potential impact on performance and injury risk (Cross et al., 2016; Quarrie et al., 2017). Whilst countermovement jump (CMJ) tests are the most common test of neuromuscular fatigue (NMF) in applied sport settings (Taylor et al., 2012), there remain some limitations to the real-world implementation of such testing for regular NMF monitoring purposes (Starling & Lambert, 2018). In particular, the maximal contractile nature of such tests results in reluctance of athletes to perform them in periods of post-match fatigue (Carling et al., 2018). As such, some have proposed tests of proprioception and postural control as novel tests of NMF, which provide the main advantage of being minimally physically demanding and not requiring maximal motivation from athletes (Austruy, 2016; Clarke et al., 2015). Therefore, the aim of this research was to assess the use of postural control measures of single-leg balance and landing on a force plate for monitoring neuromuscular fatigue in professional rugby union players.

Initially, the inter-trial and inter-test reliability of postural control measures were determined to understand the inherent variability of these tests (study 1). Then, the acute post-training changes related to specific internal and external load measures (study 2) as well as changes across different accumulated weekly load profiles (study 3) were determined in order to understand responsiveness of the tests. Finally, the use of single-leg balance and landing tests 36h post-match at the beginning of a weekly micro-cycle when monitoring tools are most applicable was investigated (study 4). To do the above, thirty-five male professional rugby union players were recruited to participate in this investigation. Measures of postural control included single-leg balance and landing tests performed on a force plate (9260AA6, Kistler Instruments, Winterthur, Switzerland) sampling at 1000 Hz. Participants performed balance tests by completing two 20 s trials on each leg with hands on hips and eyes closed.

Landing tests were performed by jumping off two legs from a starting point 1 m away and landing on one leg in the centre of the force plate. Participants performed three trials on each leg and were instructed to jump as high as possible whilst sticking and holding the landing. To investigate reliability, postural control tests were performed in the morning on the first day of training following 48 h rest on two consecutive training weeks with similar prior loads (study 1). To investigate the responsiveness to acute rugby union training loads, postural control tests were performed prior to training and again immediately following a typical training day consisting of three training sessions (gym, skills, and rugby) (study 2). To investigate the responsiveness to different accumulated internal and external load profiles, postural control tests were performed in the morning on the first day of the week across three distinct load profiles representing normal, spiked, and higher accumulated loads (study 3). And to investigate the responsiveness of postural control tests for monitoring fatigue post-match, postural control tests were performed in the morning on the first day of training following a bye week (rested) and again 7 days later on the first day of training 36h post-match (study 4).

The key findings within this research include:

Study 1

- Single-leg balance sway velocity demonstrates acceptable reliability, and superior reliability than sway velocity in the anterior-posterior and medio-lateral directions.
- Single-leg landing peak force and impulse demonstrate acceptable reliability, whilst time to stabilization should be used with caution due to the high variability and poor reliability between dominant and non-dominant legs.

Study 2

- Whilst countermovement jump eccentric rate of force development demonstrated the largest impairment following a typical rugby union training day, single-leg balance sway velocity on the non-dominant leg showed similar responsiveness to countermovement jump measures of jump height and concentric impulse.
- Bodyload, session rating of perceived exertion training load, and Banister's training impulse appear to be the main contributing factors to countermovement jump and balance impairment following typical rugby union training days.

Study 3

- Single-leg balance sway velocity was not significantly different between normal, spike, and higher three-week accumulated load profiles.
- Accumulated load profiles demonstrated a significant interaction in which single-leg landing impulse decreased over time under spike load conditions and increased over time under higher load conditions.

Study 4

- When monitoring postural control 36h post-match at the beginning of a weekly micro-cycle, most measures were within ranges observed without a prior match load (i.e. rested), however possibly small single-leg landing impulse impairments may remain.
- In higher match load groups, single-leg balance sway velocity may also demonstrate impairment 36h post-match.

Whilst the current investigation demonstrates potential responsiveness of single-leg balance sway velocity and single-leg landing impulse measures to acute and accumulated loads, the low signal to noise ratio of these tests may challenge their effectiveness. However, as demonstrated by the responsiveness of landing impulse and sway velocity on the dominant leg 36h post-match using specific thresholds for meaningful change derived from reliability results, there remains some potential for identifying individuals experiencing larger residual postural control disturbance resulting from higher match loads. It is likely that such athletes may be averse to maximal performance tests at the beginning of the weekly micro-cycle, and balance and landing tests could provide objective rationale for the appropriate modification of training and recovery. As a practical suggestion for implementation, it may be appropriate to use postural control tests early in the weekly micro-cycle to inform readiness to train, and CMJ tests later in the micro-cycle to inform readiness to perform.